Shoreline Change Mapping Using Remote Sensing and GIS

Case Study: Bushehr Province

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Abstract

In both developed and developing countries, the coastal zone is likely to undergo the most profound change in the near future. More than 60 percent of the world's population lives within 60 km of the coast. By the turn of the century two-thirds of the population (3.7 billion) in developing countries have occupied the coast. Consequently, unless careful environmental management and planning are instituted, severe conflicts over coastal space and resource utilization are likely, and the degradation of natural resources will close development options. In addition to the population pressure, the world's coastal areas and small islands are highly vulnerable to climate change. Low-lying delta, barrier coasts, low-elevation reef islands, and coral atolls are especially sensitive to the rising sea level, as well as to changes in rainfall, storm frequency, and intensity. Inundation, flooding, erosion, and saltwater intrusion are only a few of the potential impacts of climate change. Iran, connected to Caspian Sea in its north and to Persian Gulf and Gulf of Oman in its south, has totally about 5700 kilometers(scale 1:25000)coastlines and this country has the largest coastline in the Persian Gulf. A part of this coastline is located in Bushehr Province. For coastal zone monitoring, coastline extraction in various times is a fundamental work. Coastline, defined as the line of contact between land and a body of water , as one of the most important linear features on the earth's surface, holds a dynamic nature; therefore, coastal zone management requires the information about coastline changes.

The main objective of this research was to estimate the coastline changes for a period of 1990 to 2005 using RS and GIS. In this research, TM satellite data, dated 1990, were compared with ETM+ satellite data of 2000 and 2005 in order to deduce changes. Different image processing techniques have been carried out to enhance the changes from 1990 to 2005. Band math, band ratio, supervised and unsupervised classification, post classification, band selection and masking were applied using GIS software.

In this research, coastlines of the study area were extracted using satellite imagery. These changes were perpetual. However, the coastline has been changed significantly from 2001 to 2005. These great changes have happened as a consequence of development of the south Pars exclusive zone of energy (asaloyeh). A new approach was employed for coastline extraction, for which a histogram threshold together with band ratio techniques was utilized. In order to assess the accuracy of the results, they have been compared with ground truth observations. The accuracy of the extracted coastline has been estimated as 1.2 pixels (pixel size=30 m).

Keywords

Coastline Extraction; TM & ETM+sensors; Histogram Thresholding; Band Ratios; Remote Sensing

Introduction

Coastal shorelines worldwide are changing rapidly as a result of natural physical processes and human activities. Natural factors such as sediment supply, wave energy, and sea level are the primary causes of coastal changes, whereas human activities are catalysts causing disequilibrium conditions that accelerate changes. Coastline defined as the line of contact between land and the water body, is one of the most important linear features on the earth's surface, which has a dynamic nature (Winarso, et al., 2001).

Remote Sensing plays an important role in spatial data acquisition from economical perspective (Alesheikh, et al., 2003). Optical images are simple to interpret and easily obtainable. Furthermore, absorption of infrared wavelength region by water and its strong reflectance by vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water. Therefore, the images containing visible and infrared bands have been widely used for coastline mapping (DeWitt, et al., 2002). Examples of

such images are TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper) imagery (Moore, 2000). From 1972, the Landsat and other remote sensing satellites have provided digital imagery in infrared spectral bands where the land-water interface is well defined. Hence, remote sensing imagery and image processing techniques provide a possible solution to some of the problems of generating and updating the coastline maps (Winarsoet, et al., 2001).

In a general division, two main techniques can be named to extract the coastline from satellite image:

A) on-screen digitizing method is based on experience, expertise and specialist skills are concerned. In this way, the accuracy is generally better results but less on the opposite side, and additional costs will follow.

B) Automatic method has more dependence on computer in comparison with the previous method and its accuracy depending on the algorithm the software and the data used will be different. Automatic methods is based on different electromagnetic waves reflections in both of water and land based. These methods are much faster than previous methods, and usually at a lower cost.

It is worth notingthat sometimes the third method called semi-automatic can be added to the above two methods that actually is an intermediate way user try to exploit benefits both of two ways.

Coastline can even be extracted from a single band image, since the reflectance of water is nearly equal to zero in reflective infrared bands, and reflectance of absolute majority of land covers is greater than that of water. This can be achieved, for example, by histogram thresholding on one of the infrared bands of TM or ETM+ imagery.

Various methods for coastline extraction from optical imagery have been developed. Experience has shown that of the six reflective TM bands, midinfrared band 5 is the best for extracting the land-water interface (Kelley, et al., 1998). Band 5 exhibits a strong contrast between land and water features due to the high degree of absorption of mid-infrared energy by water (even turbid water) and strong reflectance of midinfrared by vegetation and natural features in this range. Of the three TM infrared bands, band 5 consistently comprises the best spectral balance of land to water. The histogram of TM band 5 ordinarily displays a sharp double peaked curve, due to tiny reflectance of water and high reflectance of vegetation (Chen, 2003). The transition zone between land and water resides between the peaks. The transition zone is the effect of mixed pixels and moisture regimes between land and water. If the reflectance values are sliced to two discrete zones, they can be depicted as water (low values) and land (higher values). But the difficulty of this method is to find the exact value, as any threshold value will be exact on some area, not all. Another method is to use the band ratio between band 4 and 2 and also, between band 5 and 2. In this method, water and land can be separated directly.

In this study, a semiautomatic method has been developed to extract coastlines using the common techniques based on remote sensing and GIS. The main aim of the method is to map coastline changes shown for Persian Gulf (Dayyer port to Naiband gulf).

Materials and Methods

Study Area

Iran, connected to Caspian Sea in its north and to Persian Gulf and Oman Sea in its south, has totally about 5700 kilometers(scale 1:25000)coastlines and this country has the largest coastline in the Persian Gulf. A part of this coastline is located in Bushehr Province.

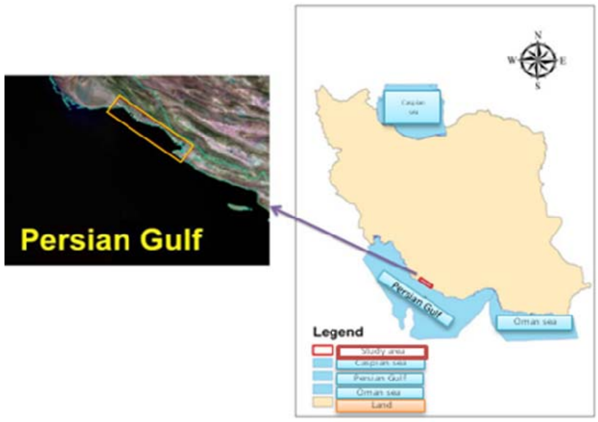

FIG. 1 THE LOCATION OF THE STUDY AREA.

The study site of this investigation is part of Bushehr province (Dayyer port to Naiband gulf- Fig.1) in Persian Gulf which is a semi-enclosed, marginal sea that is exposed to an arid, sub-tropical climate and is home to many small islands. It is located between the latitudes 24 and 30°N and longitudes of 48°and 52°30′ E. It is approximately 917 km length with its greatest width being 338 km. The Arvandrood River, the Persian Gulf's main source of fresh water, Karoon and Maroon river flow primarily from Iran and Iraq respectively into the northern end of the Persian Gulf. The Persian Gulf is about 56 kilometers width at its narrowest, in the Strait of Hormuz. The waters are overall very shallow, with a maximum depth of 93 meters and an average depth of 50 meters. The Persian

Gulf is certainly one of the most vital bodies of water on the planet, as gas and oil from Middle Eastern countries flow through it, supplying much of the world's energy.

Data

The digital images used in this research are two Landsat 7 ETM+ images and one Landsat 5 TM images. The following Table shows the spectral and spatial characteristics of Landsat 7 ETM+ and Landsat 5 TM sensors.

TABLE1 THE SPECTRAL AND SPATIAL CHARACTERISTICS OF LANDSAT 7 ETM+ AND LANDSAT 5 TM

Satellite	Sensor	Spectral Range	Band #s	Scene Size	Pixel Res
L 1-4	MSS multi-spectral	0.5-1.1 µm	1، 2، 3، 4	185X 185 km	60 meter
L 4-5	TM multi-spectral	0.45-2.35 µm	1، 2، 3، 4، 5، 7		30 meter
L 4-5	TM thermal	10.40-12.50 µm	6		120 meter
L 7	ETM+ multi-spectral	0.450-2.35 µm	1، 2، 3، 4، 5، 7		30 meter
L 7	ETM+ thermal	10.40–12.50 µm	6.1، 6.2		60 meter
L 7	Panchromatic	0.52-0.90 µm	8		15 meter

Methods

The method of threshold histogram can be used to extractcoastlines using optical images. In this way, only registered range images using infrared or near-infrared, or one of the bands in the visible range (red color), water boundary is separated from the mainland. The threshold histogram method used to extract the coastline alone is not the best method in shallow areas. Because in shallow area the near-infrared spectral range (band 4) can penetrate to a depth of one meter of water and therefore the ground floor reflection of electromagnetic wave defines this area as land. This issue in Iran's southern coast, with low slope coastal areas, increases error. As well, the littoral sediment and silt particles (especially in areas where there is a river delta) increase the amount of error in the results of this method.

On the other hand, only histogram thresholding on the Band 5 or 7 of ETM+ sensor will cause the incorrect definition of wetland as water. But this method is appropriate for areas with steep cliff and coastal states (as part of the province of Sistan and Baluchistan). Remote sensing scientists have proposed the band ratio technique to solve problems about using histogram threshold on a band. This method is based on dividing the digital number of sensor bands on digital number of other bands. To perform this operation, the band 5 is usually divided into to band 2 of ETM+ and TM. This formula for areas free of vegetation on beaches covered in a good way but in beaches that covered by vegetation species has taken the water into consideration. Therefore, for this area band 4 can be divided into 2. On the other hand, the last two bands leads to errors for the areas with rocky and bare soil.

According to vegetation, mangroves and shallow water zone in study area, a method has been developed as following:

Initially, the 1:25000 topographic maps, produced by National Iranian Cartographic Center, were used for image geometric corrections. In the next step, the corrected images were processed in order to develop two required images.

Band ratio method, i.e. simultaneously uses two conditions of Band2>Band4 & Band2>Band5 for production of binary image No.1. Then, binary image No.2 was also developed using histogram thresholding based on band 5. To enhance the accuracy of results 10 classes of land and water were defined, among which 2 classes were utilized for the image production.

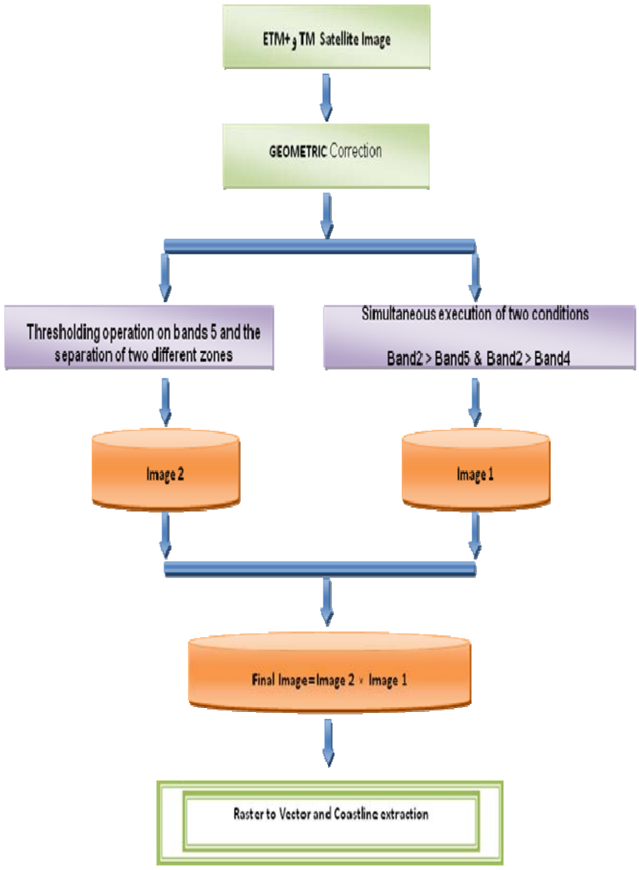

FIG. 2 FLOWCHART OF EXTRACTING COASTLINES FROM IMAGES USING OUR PROPOSED APPROACH BASED ON COMBINING THRESHOLD HISTOGRAM AND BAND RATIO METHODS

For the next step, the image No 3 was produced through multiplication of two base images. Finally, the last stage with the conduction of raster to vector shoreline was extracted from image 3. This process has been shown in Fig. 2.

To evaluate the accuracy of this approach, it is required to compare the extracted coastline from this approach with that from a ground truth map. Due to the lack of a reliable ground truth map, a ground truth image was utilized. This ground truth image was provided via fusing the ETM+ multispectral bands with ETM+ panchromatic band. Thecoastline extracted from this ground truth image via visual interpretation is assumed to be the known truth, and used to quantify the accuracy of the proposed approach in this study. This procedure is illustrated in Fig. 3. In order to evaluate the accuracy of our approach, the extracted and the known truth coastlines and quantified Root Mean Square Error (RMSE) were compared. The Euclidean distance between each vertex in extracted coastline and the nearest vertex in the truth coastline is considered as error.

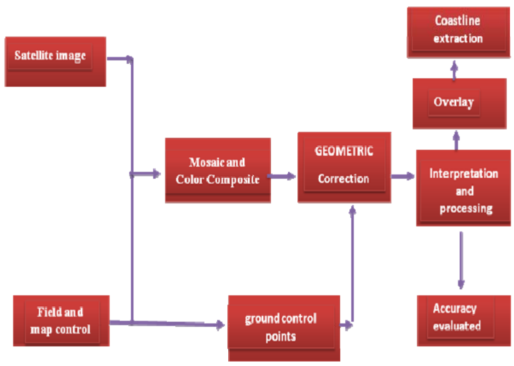

FIG. 3 PROCESS OF EXTRACTION COASTLINE FROM GROUND TRUTH IMAGE

Results

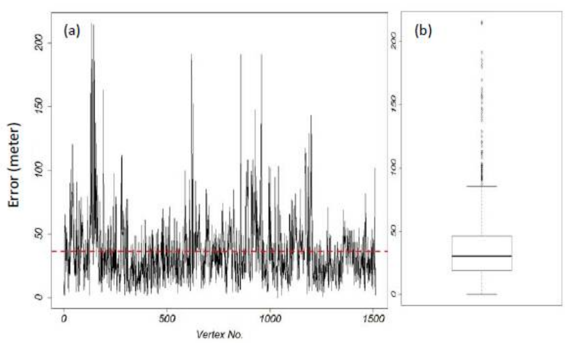

FIG. 4 DISTRIBUTION OF ERRORS ALONG COASTLINE, MEASURED AS EUCLIDEAN DISTANCE OF EACH VERTEX IN THE EXTRACTED COASTLINE TO THE NEAREST POINT IN THE TRUE COASTLINE (a), THE RED LINE ILLUSTRATES THE MEAN ERROR (RMSE); BOXPLOT SHOWS THE VARIATION OF ERRORS (b).

Our approach for extracting the coastline using satellite images was assessed on its' accuracy. The results showed that the distribution of errors ranged from the minimum of 0.2 m and the maximum of 217.3 m. The mean error (RMSE) was equal to 36.7 m which is slightly greater than 1 pixel (pixel size = 30m). Fig. 4 illustrated the distribution of absolute errors which was measured along the coastline.

The proposed approach in this study was also used to extract the coastline in different years. Comparison of the coastlines showed that changes in coastlines are perpetual. However, the coastline has been changed greatly between the years of 2001 and 2005. These changes were the consequences of developing the south Pars exclusive zone of energy (Asaloyeh, illustrated in Fig. 5). Also, in this investigation, a new approach was applied to coastline extraction, in which histogram thresholding and band ratio techniques were utilized together.

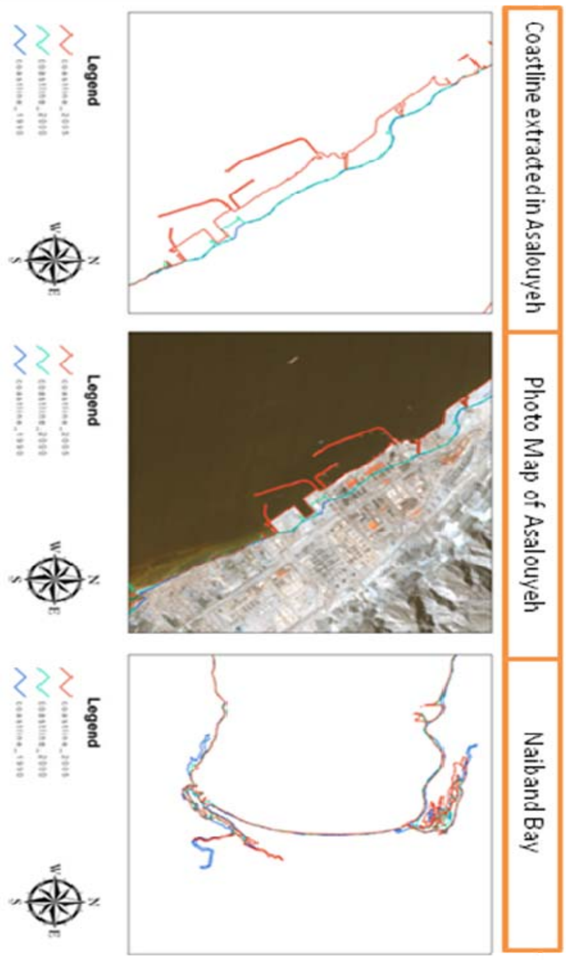

FIG. 5 COASTLINE EXTRACTED IN ASALOUYEH AND NAIBAND BAY BY STUDY METHOD

Discussion and Conclusion

In this study, a new approach has been proposed and

developed to extract the coastline using satellite images, then the role of remote sensing and GIS to support coastal programming as well has been discussed. Erosion and sedimentation are basic factors for the changing of Coastline. At first, mapping seems to be a simple application of remote sensing data, but in practice semi-automated or automated extraction of the land/water boundaries is more difficult than one would expect (Kaichang, 1999). Because the frequent lack of consistency, sufficient intensity contrast between land and water regions (especially in the Swamp and muddy lands) and the complications of distinguishing coastline from other object boundaries, coastline extraction is a difficult task for most edge detection or segmentation techniques (Cracknell, 1999).

This study shows that the band ratios of 2/5 and 2/4 improve the potential of interpretation which can be used to change detection of Persian Gulf coastline. Despite the successful applications of satellite images, it should be noted that the quality of the images remains an important factor for coastline extraction. The success of the dissimilar methods still depends upon whether considerable contrast can be achieved between water and land mass and to a lesser degree it also depends on the homogeneity of the water or land mass. The relative accuracy is evaluated in this research based on the comparison between the processing derived coastline and the coastline visually interpreted from the original satellite images. Extensive visual comparison shows that the relative accuracy of the results of the extracted coastlines is within one image pixel compared with the human visual interpretation of the coastline features. In real world applications, the absolute accuracy of the geographical position of the derived coastline is essential.

The proposed approach based on integration of the band ratio and histogram thresholding techniques could be applied to Landsat MSS, TM and ETM + imageries to map changes of coastal land forms such as Persian gulf shorelines. The technique produces vector files of the coastline which can be analyzed using GIS to estimate rates of change over relatively long time periods or used for modeling long term changes. The synoptic capabilities of remote sensing provide a useful reconnaissance tool to target more detailed field surveys to neighborhoods of change. This study has indicated that modern image processing techniques can provide good information for the change detection and coastline extraction that may be used for any coastal management program. In the future investigations of Persian Gulf, shorelines could be targeted for more detailed monitoring in the field by the processing of high resolution images like Ikonos and Quickbird simultaneously.

REFERENCES

Alesheikh, et al., 2007, “Generation the coastline change map for Urmia Lake by TM and ETM+ imagery”

Aplin, P. (2004), Remote sensing land cover: Progress in Physical Geography, vol. 28, pp. 283-293

Birkett, C., and Mason, I. (1995), A new global lakes database for remote sensing programmed studying climatically sensitive large lakes. Journal of Great Lakes Research, vol.21 (3), pp. 307-318

Birkett, C.M. (1994), Radar altimetry-a new concept in monitoring global lake level changes. Eos Trans. AGU, vol. 75 (24), pp. 273–275

Birkett, C.M., Mertes, L.A.K., Dunne, T., Costa, M. and Jasinski, J. (2002), Altimetric remote sensing of the Amazon: Application of satellite radar altimetry. JGR, vol. 107 (D20), pp. 8059

Braud, D. H. and Feng, W. (1998), Semi-automated construction of the Louisiana coastline digital land/water boundary using Landsat Thematic Mapper satellite imageries. Department of Geography & Anthropology, Technical Report Series 97-002

Chen, L.C. and Shyu, C.C, (1998).”Automated extraction of shorelines from optical and SAR images”

Cracknell, A. P. (1999), Remote sensing techniques in estuaries and coastal zones- an update. International Journal of Remote Sensing, vol. 19(3) pp.485-496.

Curran, P.J. (1985), Principles of remote sensing, London Scientific and Technical Group, Essex, England, pp.282

Dalton, J.A. and Kite, G.W. (1995), A first look at using the TOPEX/Poseidon satellite radar altimeter for measuring lake levels. Proceedings of the International Workshop on the Application of Remote Sensing in Hydrology , Saskatoon, Canada, NHRI Symp. 0838-1984, No. 14, Kite, G.W., Pietroniro, A. and Pultz, T.D. (Eds.), 105–112.

DeWitt H., JR. Weiwen Feng, “Semi-Automated Construction of the Louisiana Coastline Digital Land-Water Boundary Using Landsat TM Imagery”

Duker, L. and Borre, L. (2001), Biodiversity conservation of the world's lakes: a preliminary framework for

identifying priorities. LakeNet Report Series Number 2. Annapolis, Maryland USA

eCognition User Guide (2003), http://www.definiens-imaging.com.

Ekstrand, S. (1994), Assessment of forest damage with Landsat TM: correction for varying forest stand characteristics. Remote Sensing Environ no.47, pp. 291-302

ERDAS IMAGIANE 8.7 (2003), ERDAS Field Guide™, Fifth Edition, Revised and Expanded, ERDAS, Inc., Atlanta, Georgia

Frazier, P. S., and Page, K.J. (2000), Water body detection and delineation with Landsat TM data. Photogrammetric Engineering and remote Sensing, vol. 66 (12), pp. 1461-1467

Ghosh, S.K. and Shankar, B. (2000), Segmentation of remotely sensed images with fuzzy thresholding, and quantitative evaluation. International Journal of Remote Sensing, vol. 21 (11), pp. 2269-2300

Hall, O. and Hay, G. (2003), Multiscale object-specific approach to digital change detection. International Journal of Applied Earth Observation and Geoinformation, vol. 4, pp. 311-327

http://oceanservice.noaa.gov/mapfinder/products/tsheets/welcome.html

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/gr_regional_chart.cfm?regionid=metu®ion=&reservoir_name=UrmiaJabbarlooye

http://www.worldlakes.org

Jupp, D.L.B., (1988), “Background and extensions to depth of penetration (DOP) mapping in shallow coastal waters”. Proceeding of the symposium on remote sensing of coastal zone, Gold Coast, Queensland, September 1988, IV.2.1-IV.2.19

Rasuly A. A., et al., (2010), “Monitoring of Caspian Sea coastline changes using object-oriented techniques”, International Conference on Ecological Informatics and Ecosystem Conservation

S. Pirasteh, (2006), “Investigation of Kouhestak-Karian Coastline changes using GIS”, Map Asia 2006.

S. Pirasteh, (2006), “Change detection of coastal zone in Persian Gulf (1970 to 2002): Using topography map and remotely sensed data”, Map Asia

Winarso G., (2001). The potential application remote sensing data for coastal study. Singapore. 22nd Asian Conference on Remote Sensing. Singapore. Refer from: http://gisdevelopment.net/aars/acrs